OPTICAL SYSTEM AND OPTICAL APPARATUS INCLUDING SAME

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an optical system and an optical apparatus including the same, which are suitable for an image pickup apparatus using an image pickup element such as a digital video camera, a digital still camera, and a broadcasting camera, or for an optical apparatus such as a camera that uses a silver halide photographic film.

Description of the Related Art

[0002] Appearance of an out-of-focus image (a blurry image) is occasionally an important optical performance of an image pickup optical system. One of factors to dictate the appearance of a blurry image is light amount distribution in the blurry image. In particular, an aspect of light amount distribution that gradually reduces light amount near the contour in the blurry image tends to be preferred.

[0003] Such light amount distribution can be obtained by an apodization effect. The apodization effect can be obtained by using an optical element designed to reduce transmissivity with increasing distance away from the optical axis.

[0004] International Publication No. WO2016/039147 discloses an optical system provided with an optical element having transmissivity distribution in order to obtain the apodization effect.

SUMMARY OF THE INVENTION

[0005] An optical system of the present invention includes a plurality of lenses including an aspheric lens having a first aspheric surface, and a light absorption portion arranged on an optical axis and having thickness distribution in a direction perpendicular to the optical axis. Here, the light absorption portion includes a second aspheric surface. Moreover, the following conditional expressions are satisfied:

$$|nG \times XG/(nF \times XF)| > 1.00; \text{ and}$$

$$0.800 \leq hG/hF \leq 1.30,$$

where nG is a refractive index of the aspheric lens at a wavelength of 550 nm, nF is a refractive index of the light absorption portion at the wavelength of 550 nm, XG is an aspheric sag amount of the first aspheric surface, XF is an aspheric sag amount of the second aspheric surface, hG is a height of a position on the first aspheric surface through which a marginal ray of an axial ray passes, and hF is a height of a position on the second aspheric surface through which the marginal ray of the axial ray passes.

[0006] Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a cross-sectional view of an optical system of Example 1.

[0008] FIG. **2** illustrates aberration diagrams of the optical system of Example 1.

[0009] FIG. **3** is a cross-sectional view of an optical system of Example 2.

[0010] FIG. **4** illustrates aberration diagrams of the optical system of Example 2.

[0011] FIG. **5** is a cross-sectional view of an optical system of Example 3.

[0012] FIG. **6** illustrates aberration diagrams of the optical system of Example 3.

[0013] FIG. **7** is a graph showing thickness distribution of light absorption portions of each Examples.

[0014] FIG. **8** is a schematic diagram of an image pickup apparatus.

DESCRIPTION OF THE EMBODIMENTS

[0015] Examples of an optical system and an optical apparatus including the same of the present invention will be described below.

[0016] FIGS. **1**, **3**, and **5** are cross-sectional views of optical systems of Examples 1, 2, and 3 when focused at infinity, respectively.

[0017] In each lens cross-sectional view, reference sign SP denotes an aperture stop. Meanwhile, reference sign IP denotes an image plane. When the optical system of each example is used as an image pickup optical system of a video camera or a digital camera, an image pickup element such as a CCD sensor and a CMOS sensor is arranged on the image plane IP. When the optical system of each example is used as an image pickup optical system of a silver halide film camera, a film is arranged on the image plane IP. In the meantime, reference sign OA denotes an optical axis.

[0018] The optical system of each example includes a plurality of lenses inclusive of an aspheric lens having an aspheric surface, and a light absorption portion having transmissivity distribution in a direction perpendicular to the optical axis.

[0019] In an optical system **1** of Example 1 shown in FIG. **1** and an optical system **2** of Example 2 shown in FIG. **3**, reference sign GE denotes an aspheric lens and reference sign FE denotes a light absorption portion. In an optical system **3** of Example 3 shown in FIG. **5**, reference sign GE denotes an aspheric lens and reference signs FE**1** and FE**2** denote light absorption portions.

[0020] At least one of optical surfaces of the aspheric lens GE, and one of a light incident surface and a light exit surface of the light absorption portion FE are each formed into an aspheric surface. In other words, the aspheric lens GE includes a first aspheric surface and the light absorption portion FE includes a second aspheric surface. Such an aspheric surface may be of any surface shape as long as it is different from a spherical shape. Examples of the aspheric surface include a paraboloidal surface, an ellipsoidal surface, a hyperboloidal surface, and the like. Meanwhile, the aspheric surface may include a spherical surface in part of its region.

[0021] The light absorption portion FE contains a light-absorbing material. The transmissivity distribution is formed by changing the thickness of the light absorption portion FE in a direction orthogonal to the optical axis. The transmissivity distribution of the light absorption portion FE may be transmissivity distribution that can bring about the apodization effect. Such transmissivity distribution may be transmissivity distribution in which transmissivity is continuously reduced from the optical axis to the periphery, or transmissivity distribution in which transmissivity is